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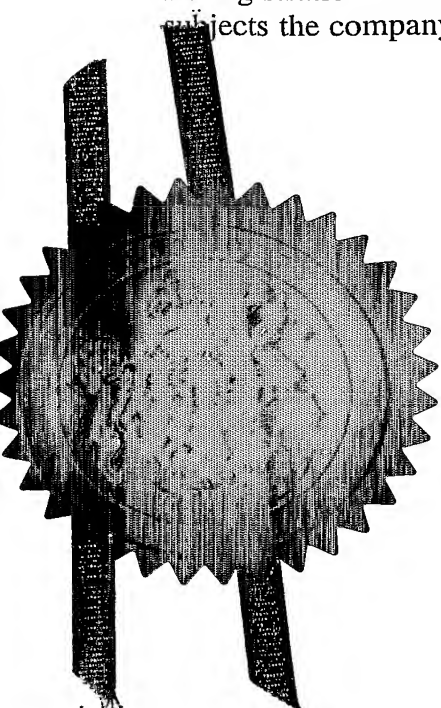
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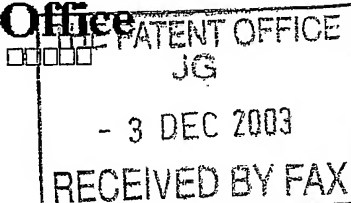
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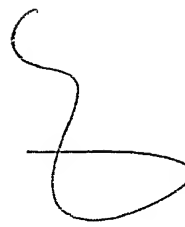
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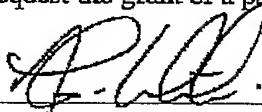
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## DESCRIPTION

## 2D/3D DISPLAYS

5

The present invention relates to display devices.

In this invention disclosure we discuss displays that are switchable between a two- and a three-dimensional mode.

10 In a most simple embodiment a three-dimensional display based on a LCD can be constructed as follows. Between the backlight and the LCD a mask with vertical slits is placed, see Figure 1. This mask blocks most of the light and at certain position it creates horizontal lines of light. The LCD sub-pixels are illuminated by these light lines. Depending of the position of the  
15 viewer, only certain sub-pixels are visible. Even more, both eyes see a different sub-pixel which allows stereo information to be shown.

In Figure 1 we have light lines that repeat each other after 6 sub-pixels. So, there are six different view positions and the viewer has some moving freedom. We call this an auto-stereoscopic display.

20 The use of a mask is not the most elegant and efficient way to create light lines. It is more favorable to use a dedicated backlight as for instance disclosed in our pending United Kingdom patent application 0326005.6 (PHGB030200).

25 The use of vertical light lines is also not very favorable. A small error in the pitch of the lines with respect to the pitch of the LCD sub-pixels will result in a Moiré pattern. To avoid this, the light lines should have a slanted angle with respect to the vertical color stripes of the LCD. Such a construction for a three-dimensional auto-stereoscopic display based on a lenticular screen is described in United States patent US6064424. The slanted angle not only  
30 reduces the Moiré artifacts but also result in a distribution of the resolution degradation in the horizontal and vertical direction.

As mentioned above, a three-dimensional display sacrifices resolution to create a depth impression. This implies that normal two-dimensional information, like text, looks not acceptable on these displays. Therefore, it is desired that displays are switchable between a two- and three-dimensional mode. Preferably, this switching should be locally, such that we can create windows with three-dimensional information in a two-dimensional surrounding (and the reverse).

In this application we describe a number of embodiments of displays that are switchable between a two- and three-dimensional mode. In these displays we use a dedicated foil with very specific scattering properties: the foil is translucent for one linear polarization direction and scattering for the other. This foil is based on birefringence. Details about this foil are described further below in the present application. In combination with a polarization switch, a LC cell ( $\lambda/4$  cell), this foil allows us to switch between a two- and three-dimensional mode.

Another switchable display based on birefringence is disclosed by Ocuity in their application WO03/015424A2. In this display a birefringe lenticular in front of the display is used. A sketch of the Ocuity embodiment is shown in Figure 2. The LCD is not equipped with an analyzing polar. On top of the LCD a lenticular is placed and an additional LC cell which is used as a switchable  $\lambda/4$  cell and finally there is the analyzing polar.

The switchable  $\lambda/4$  cell is used to choose the 2D or 3D mode. In the 3D mode the cell does not alter the polarization and the light that is diffracted by the lenses passes through the analyzing polar. In the 2D mode the  $\lambda/4$  cell does alter the polarization and light that passes the birefringence lenses unaltered passes through the analyzing polar. This implies that the display is used in a normally black mode and normally white mode for the 2D and 3D mode respectively (or the opposite). A drawback of this is that the normally black mode is known to result in a worse image quality. In addition, it is favorable for the 2D mode not to have any appliances between the display and the viewer.

In the discussion to follow we will assume that we have an LCD screen without rear polar. The retarders and the front polar (analyzer) are still present.

In the following we discuss all seven embodiments and we will discuss for each embodiment some preferred options.

5 In this section we discuss seven possible embodiments of an auto-stereoscopic display. In all these embodiments we use a polarization dependent scatterer. Such a foil is translucent for one linear polarization direction and scatters the light for another polarization direction. The switching between a two- and three-dimensional mode is performed with a LC cell.

10 In all embodiments we use a stack of elements, where the first element is a backlight with light-lines, as described in the above-mentioned GB0326005.6 and the last element is a LCD without rear polarizer. In the first 6 embodiments there are between these two elements a lenticular screen, a LC cell and a polarization dependent scatterer. Optionally, there is an  
15 additional polarizer.

The last embodiment does not use a lenticular screen but the remainder of the stack between the backlight and the LCD without rear polarizer is the same. That there is no lenticular is a cost advantage, although the light lines are relatively far away from the LC-cells in the LCD. Consequently, the size of  
20 the viewing cones is small and the construction is only acceptable if we use relatively thin (glass) substrates.

For instance, in a mobile phone application the viewing distance is typically  $L = 400\text{mm}$ . The eyes of the viewer are  $E = 65\text{mm}$  apart on average. If the pixel size is  $p = 45\mu\text{m}$ , this implies that the light lines should be at:

25 
$$d = p L/E = 270\mu\text{m}$$

from the LC cell, see Figure 3. Most mobile phones have a glass thickness of  $400\mu\text{m}$  or more.

In the discussion of the embodiments we will denote by P and S the polarization direction of the light, light which is linearly polarized and of which  
30 the polarization direction is parallel or orthogonal to the plane of drawing respectively. In all embodiments it is possible to exchange the P and S polarization without affecting the functioning of the embodiments.

Finally, we remark that the six embodiments we describe are all possible combinations of lenticular, polarization dependent scatterer and LC cell. Several of these embodiments need an additional polar to get a working display.

5

#### Embodiment 1

In the first embodiment we use a stack of a backlight with light lines, a lenticular, a polar, a LC cell, a polarization dependent scatterer and a LCD screen without rear polar. An illustration of this stack is given in Figure 4.

10

To explain the functioning of this stack let us assume that the polarization dependent scatterer is translucent for light with polarization P. Furthermore, we assume that the LC is able to change (preferably locally), the polarization of the light from S to P and from P to S.

15

The backlight emits light along light lines with both polarization directions S and P. For both polarization directions the light lines are imaged by the lenticular. The polar selects a polarization direction, say P. If the LC does not alter the polarization of the light, the light will also pass the polarization dependent scatterer unaltered. Effectively, the LCD will be lit by light lines with polarization P and a three-dimensional impression can be created by applying the right video information to the LCD and drive the LCD in a normally white mode.

20

If the LC cell alters the polarization of the light from P to S, this light will also be scattered by the scatterer and the LCD will be lit uniformly by light with polarization S. In this case the LCD is driven in a normally black mode.

25

The normally white and normally black mode that correspond to the 3D and 2D mode can be interchanged, depending on the orientation of the retarders and analyzer on the LCD.

In an alternative embodiment the polar might be placed between the lenticular and the LC cell as well.

30

Finally, the orientation of the polar and the polarization dependent foil should be aligned with the lenticular. The refraction at the lens surfaces results in a polarization rotation if the polarization is not parallel or orthogonal to the



lens surfaces. This implies that in a system in which the lenticular is placed under a slanted angle, the polar and the foil need to have the same slanted angle.

## 5 Embodiment 2

In the second embodiment we use a stack of a backlight with light lines, a polarizer, a LC cell, a lenticular, the polarization dependent scatterer and a LCD with rear polar. An illustration of this stack is given in Figure 5. Compared with the first embodiment the position of the polarization dependent scatterer and the polarizer is interchanged.

To explain the functioning of this stack let us assume that the polarization dependent scatterer is translucent for light with polarization P. Furthermore, we assume that the LC is able to change (preferably locally), the polarization of the light from S to P and from P to S.

15 The backlight emits light along light lines with both polarization directions S and P. For both polarization directions the light lines are imaged by the lenticular. The polarization dependent scatterer scatters the light with polarization S. If the LC cell does not alter the polarization of the light, the scattered light with polarization S is blocked by the rear polarizer of the LCD.  
20 The light with polarization P is imaged in light lines and used to lit the LCD.

If the LC cell does alter the polarization of the light, the scattered light with polarization S before and P after the LC cell is used to lit the LCD uniformly.

In a preferred embodiment there is an additional polarization dependent  
25 diffusive layer placed between the lenticular and the polarizer. This layer should be positioned at the image of the light lines and only scatter the light with polarization P. In this way the opening angle of the images of the light lines is increased in the 3D mode and the uniformity of the illumination is increased in the 2D mode. An illustration of this principle is given in Figure 9  
30 for the fifth embodiment.

## Embodiment 3

In the third embodiment we use a stack of a backlight with light lines, a polarizer, a LC cell, a lenticular, a polarization dependent scatterer and a LCD without rear polar. An illustration of this stack is given in Figure 6.

To explain the functioning of this stack let us assume that the polarization dependent scatterer is translucent for light with polarization P. Furthermore, we assume that the LC is able to change (preferably locally), the polarization of the light from S to P and from P to S.

The backlight emits light along light lines with both polarization directions S and P. The polarizer blocks one of the polarizations, say S. If the LC cell does not alter the polarization of the light, the light which has polarization P only is imaged by the lenticulars to light lines. The polarization dependent scatterer is translucent for this light and hence, the LCD is lit by light lines with polarization P. In this case the LCD needs to be driven in the normally white mode.

If the LC cell does alter the polarization of the light, the light with polarization S is scattered by the polarization dependent scatterer and the LCD is lit uniformly by S polarized light. In this case the LCD needs to be driven in the normally black mode.

The normally white and normally black mode that correspond to the 3D and 2D mode can be interchanged, depending on the orientation of the retarders and analyzer on the LCD.

In a preferred embodiment the S and P polarization discussed should be along and orthogonal (or orthogonal and along) to the lenticulars. In this way polarization rotation as a side effect of the lens action is avoided. This implies that if the light lines are slanted with respect to the color filter orientation of the LCD, the polarization directions should be slanted over the same angle.

#### Embodiment 4

In the fourth embodiment we use a stack of a backlight with light lines, a polarizer, a LC cell, a polarization dependent scatterer, a lenticular and a LCD without rear polar. An illustration of this stack is given in Figure 7. Compared

to the third embodiment, the position of the lenticular and polarization dependent scatterer are interchanged.

To explain the functioning of this stack let us assume that the polarization dependent scatterer is translucent for light with polarization P. Furthermore, we assume that the LC is able to change (preferably locally), the polarization of the light from S to P and from P to S.

The backlight emits light along light lines with both polarization directions S and P. The polarizer blocks one of the polarizations, say S. If the LC cell does not alter the polarization of the light, the light passes the polarization dependent scatterer unaltered. The lenticulars image the light and the LCD is lit by light lines with polarization P. In this case the LCD needs to be driven in the normally white mode.

If the LC cell does alter the polarization of the light, the light with polarization S is scattered by the polarization dependent scatterer. The lenticular is not able to focus the scattered light and the LCD is lit uniformly by S polarized light. In this case the LCD needs to be driven in the normally black mode.

The normally white and normally black mode that correspond to the 3D and 2D mode can be interchanged, depending on the orientation of the retarders and analyzer on the LCD.

In a preferred embodiment the S and P polarization discussed should be along and orthogonal (or orthogonal and along) to the lenticulars. In this way polarization rotation as a side effect of the lens action is avoided. This implies that if the light lines are slanted with respect to the color filter orientation of the LCD, the polarization directions should be slanted over the same angle.

#### Embodiment 5

In the fifth embodiment we use a stack of a backlight with light lines, a polarization dependent scatterer, a LC cell, a lenticular and a polar and a LCD with rear polar. An illustration of this stack is given in Figure 8.

To explain the functioning of this stack let us assume that the polarization dependent scatterer is translucent for light with polarization P. Furthermore, we assume that the LC is able to change (preferably locally), the polarization of the light from S to P and from P to S.

5 The backlight emits light along light lines with both polarization directions S and P. The polarization dependent scatterer scatters the light with polarization S. If the LC cell does not alter the polarization of the light, the scattered light with polarization S is blocked by the rear polarizer of the LCD. The light with polarization P is imaged by the lenticular and the LCD is lit by  
10 light lines.

If the LC cell does alter the polarization of the light, it is the light scattered by the polarization that hits the LCD uniformly. The lenticular is not able to focus this scattered light. The light that is unaltered by the polarization dependent scatterer is blocked by the rear polarizer of the LCD.

15 In a preferred embodiment there is an additional polarization dependent diffusive layer placed between the lenticular and the polarizer. This layer should be positioned at the image of the light lines and only scatter the light with polarization P. In this way the opening angle of the images of the light lines is increased in the 3D mode and the uniformity of the illumination is  
20 increased in the 2D mode. An illustration of this principle is given in Figure 9.

In a preferred embodiment the S and P polarization discussed should be along and orthogonal (or orthogonal and along) to the lenticulars. In this way polarization rotation as a side effect of the lens action is avoided. This implies that if the light lines are slanted with respect to the color filter  
25 orientation of the LCD, the polarization directions should be slanted over the same angle and the polarization dependent foil should be rotated as well.

#### Embodiment 6

In the sixth embodiment we use a stack of a backlight with light lines, a  
30 polarization dependent scatterer, a lenticular, a LC cell and a LCD with rear polar. An illustration of this stack is given in Figure 10. Compared to the fifth embodiment the positions of the lenticular and the LC cell are interchanged.

To explain the functioning of this stack let us assume that the polarization dependent scatterer is translucent for light with polarization P. Furthermore, we assume that the LC is able to change (preferably locally), the polarization of the light from S to P and from P to S.

5       The backlight emits light along light lines with both polarization directions S and P. The polarization dependent scatterer scatters the light with polarization S. The lenticular images the light with polarization P to light lines. If the LC cell does not alter the polarization of the light, the light scattered by the polarization dependent scatterer is blocked by the rear polarizer of the  
10       LCD. Hence, the LCD is lit by light lines.

If the LC cell does alter the polarization of the light, the light scattered by the polarization dependent scatterer is passed by the rear polarizer of the LCD. The lenticular is not able to focus this scattered light. Hence, the LCD is lit uniformly.

15       In a preferred embodiment there is, like in the fifth embodiment, an additional polarization dependent diffusive layer placed between the lenticular and the polarizer. This layer should be positioned at the image of the light lines and only scatter the light with polarization P. In this way the opening angle of the images of the light lines is increased in the 3D mode and the uniformity of  
20       the illumination is increased in the 2D mode. An illustration of this principle is given in Figure 9 for the fifth embodiment.

In a preferred embodiment the S and P polarization discussed should be along and orthogonal (or orthogonal and along) to the lenticulars. In this way polarization rotation as a side effect of the lens action is avoided. This  
25       implies that if the light lines are slanted with respect to the color filter orientation of the LCD, the polarization directions should be slanted over the same angle and the polarization dependent foil should be rotated as well.

#### Embodiment 7

30       In the seventh embodiment we use a stack of a backlight with light lines, a polarizer, a LC cell, a polarizing dependent scatterer and a LCD without rear

polar. An illustration of this stack is given in Figure 11. This is the same stack as in the first, third and fourth embodiment, but without the lenticular screen.

To explain the functioning of this stack let us assume that the polarization dependent scatterer is translucent for light with polarization P.  
5 Furthermore, we assume that the LC is able to change (preferably locally), the polarization of the light from S to P and from P to S.

The backlight emits light along light lines with both polarization directions S and P. The polar selects a polarization direction, say P. If the LC does not alter the polarization of the light, the light will also pass the  
10 polarization dependent scatterer unaltered. The LCD will be lit by light lines with polarization P and a three-dimensional impression can be created by applying the right video information to the LCD and drive the LCD in a normally white mode.

If the LC cell alters the polarization of the light from P to S, this light will  
15 also be scattered by the scatterer and the LCD will be lit uniformly by light with polarization S. In this case the LCD is driven in a normally black mode.

The normally white and normally black mode that correspond to the 3D and 2D mode can be interchanged, depending on the orientation of the retarders and analyzer on the LCD.

20

Considering now the foil, a problem with the prior art to be solved is the conventional use of a non-standard relatively complex polarization-selective microlens array. This lens array is made from high cost materials and with a complex fabrication method.

25 The Applicants solution is to use an optical stack with a polarization-selectively scattering element made from low cost materials and with simple manufacturing process in combination with a standard (isotropic) microlens array.

This has the advantage of lower costs of components and less complex  
30 manufacturing.

The micro-lenses create a good 3D image both with the P- and with the S-polarized light. The scattering foil does not scatter the P-polarization.

Hence with the polarization rotator and top polarizer in the P-state, a 3D image can be observed.

The S-polarized light is also focussed by the micro-lenses but now the scattering foil is acting as a diffuser and destroys the 3D image.

5 The polarization rotator and top polarizer are now put in the S-state, and the grey levels are electronically inverted.

Embodiments of this aspect of the invention are shown in Figures 12 to 18. More embodiments are possible where the scattering foil, the microlenses and the polarization rotator are stacked in a different order.

10 In this application we described embodiments of a 2D/3D switchable display based on a polarization dependent scattering foil. In the embodiments we have between a backlight with light lines and a LCD without rear polarizer a combination of a lenticular screen, a LC cell, a polarizer and the polarizing dependent scattering foil.

15 Some of the embodiments, 1, 3, 4 and 7 need to drive the LCD in a normally black mode for the 2D mode and a normally white mode for the 3D mode (or the reverse). This is less preferred since the normally black mode is known, among others, to result in less contrast.

20 There is an eighth embodiment possible, in which the polarization dependent scatterer and the polar of the seventh embodiment are exchanged. This embodiment is of less interest, since the scatterer is close to the light lines of the backlight and in the 2D mode it is less likely that the LCD is lit uniformly by this construction.

25 Preferably the LC cell used to select the 2D and 3D mode should be equipped with layers (retarders) that improve the viewing angle behavior. Otherwise, it is possible that the LC cell will only rotate the polarization direction over 90 degrees in the orthogonal direction. Under an angle the rotation is different and consequently, a viewer will see the 2D and 3D mode at the same time if he views the display under an angle.

30 In preferred embodiments the LC cell has column and row electrodes such that we can select parts of the display to be in a two-dimensional mode

while other parts are in a three-dimensional mode. For this purpose the LC cell might be driven by means of a passive matrix scheme.

In all embodiments described, the LC cell did not alter the polarization state if the display was in the two-dimensional mode. It is straightforward (for a person skilled in the art) to come up with variants, in which the LC does alter the polarization state in the two-dimensional mode and does not in the three-dimensional mode.

In conclusion, of all presented embodiment the second, fifth and sixth embodiment are the most interesting ones. Both do not use a normally black or white mode depending on the two- and three-dimensional display mode. So, the display quality is not compromised in one of the two modes. If we want to create a display in which parts of the display are in the two- and other parts in the three-dimensional mode, the second and sixth embodiment are slightly more favorable than the fifth. In the fifth embodiment the LC cell is relatively far away from the LCD. At the boundaries of the two- and three-dimensional regions this might result in a region which partly lit by light lines and partly uniformly which is undesired.

In summary, we propose a stack that consists of firstly a backlight with light lines and finally a LCD without rear polarizer. In between those two components there can be in arbitrary order a polarization dependent scatterer, optionally a lenticular, a LC cell and optionally a polar.

In the foregoing we have also described:

a display system capable of displaying 3D images and capable of switching locally or as a whole to a 2D mode comprising a polarization-selectively scattering element;

a display in which the polarization-selectively scattering element is stretched Pet or PEN foil; and

a display in which the polarization-selectively scattering element is coated stretched and embossed PET or PEN foil.

From reading the present disclosure, other modifications will be apparent to persons skilled in the art. Such modifications may involve other



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features which are already known in the design, manufacture and use of communications systems and/or data network access apparatus and devices and component parts thereof and which may be used instead of or in addition to features already described herein.

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## CLAIMS

1. A display device substantially as hereinbefore described with respect to one or more of the accompanying drawings.

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## ABSTRACT

## 2D/3D DISPLAYS

5        Embodiments of a switchable 2D/3D auto-stereoscopic display based  
on a polarization dependent scattering foil are described. In all embodiments  
there is a stack of elements where the first element is a backlight that emits  
light along light-lines and the last element is a LCD without rear polarizer.  
Between these two elements there are different combinations proposed of a  
10    lenticular, a LC cell, a polarizer and the polarization dependent scatterer.

(Fig. 4)



1/11

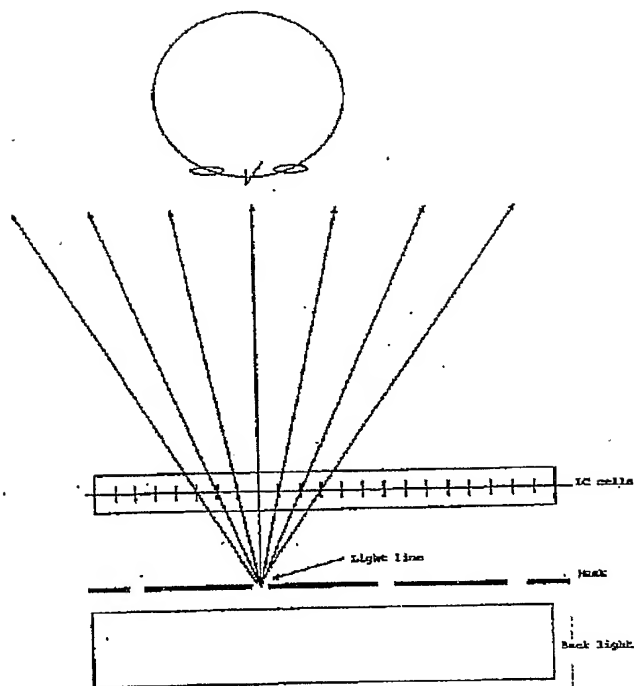


FIGURE 1

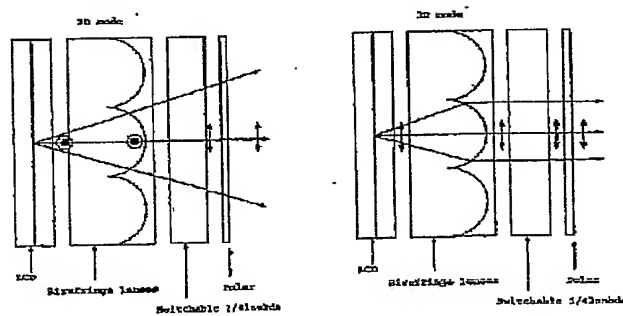


FIGURE 2.

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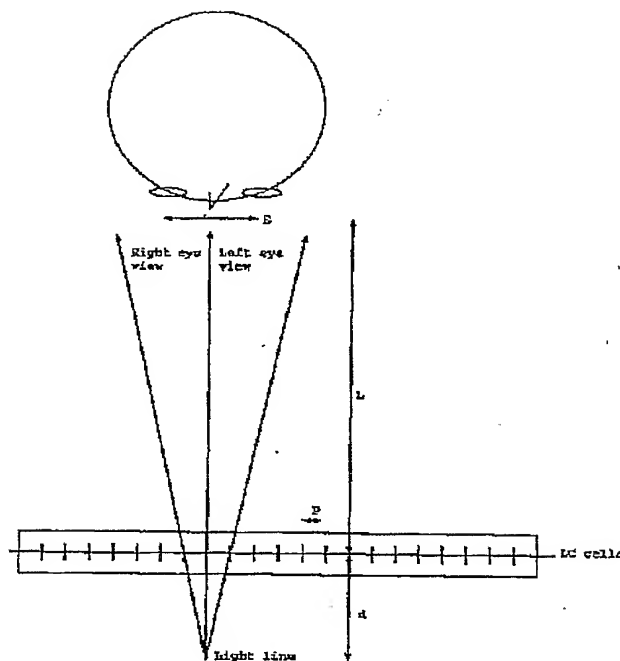


FIGURE 3

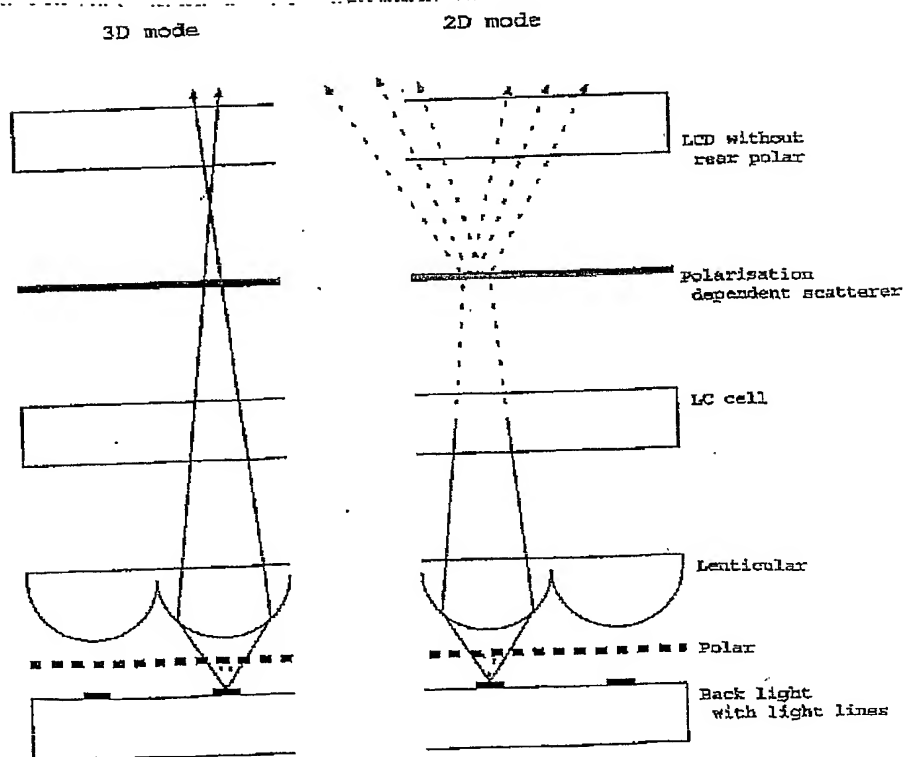


FIGURE 4

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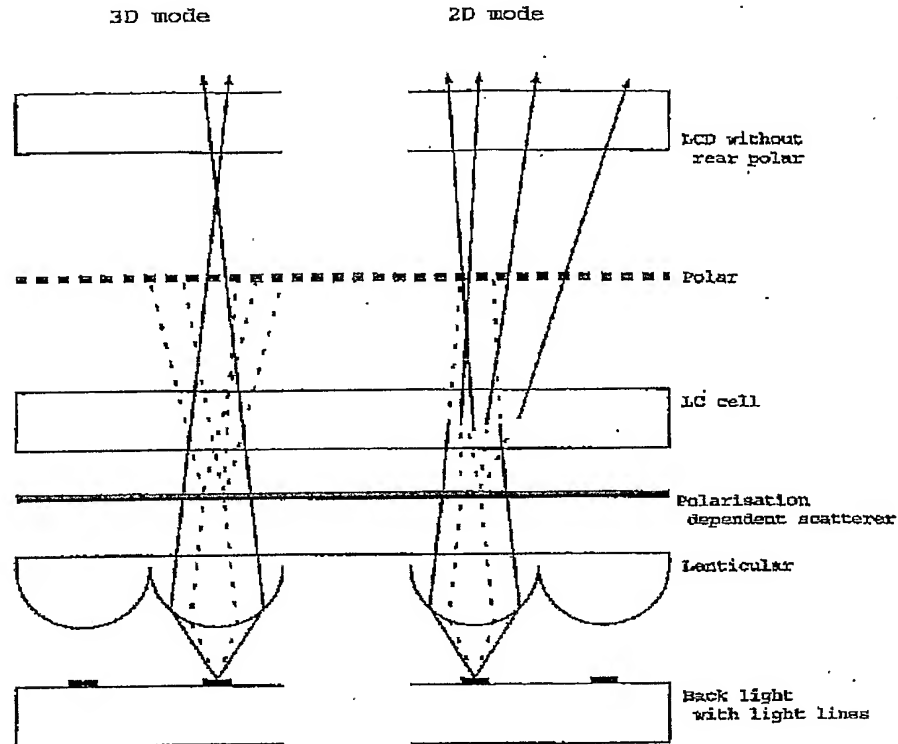


FIGURE 5

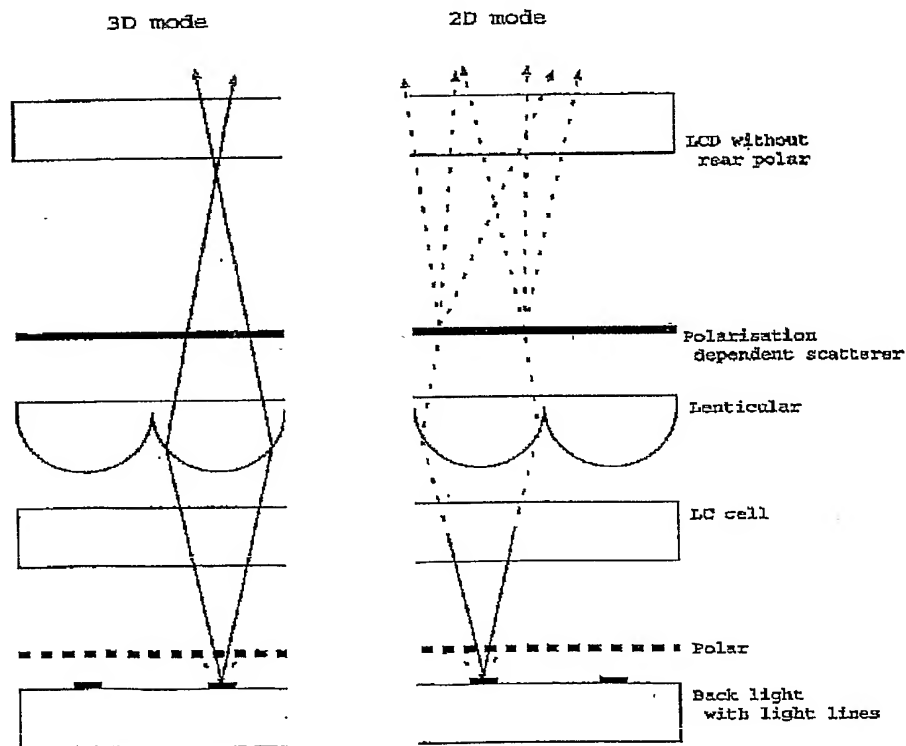


FIGURE 6

PHGB 030215



4/11

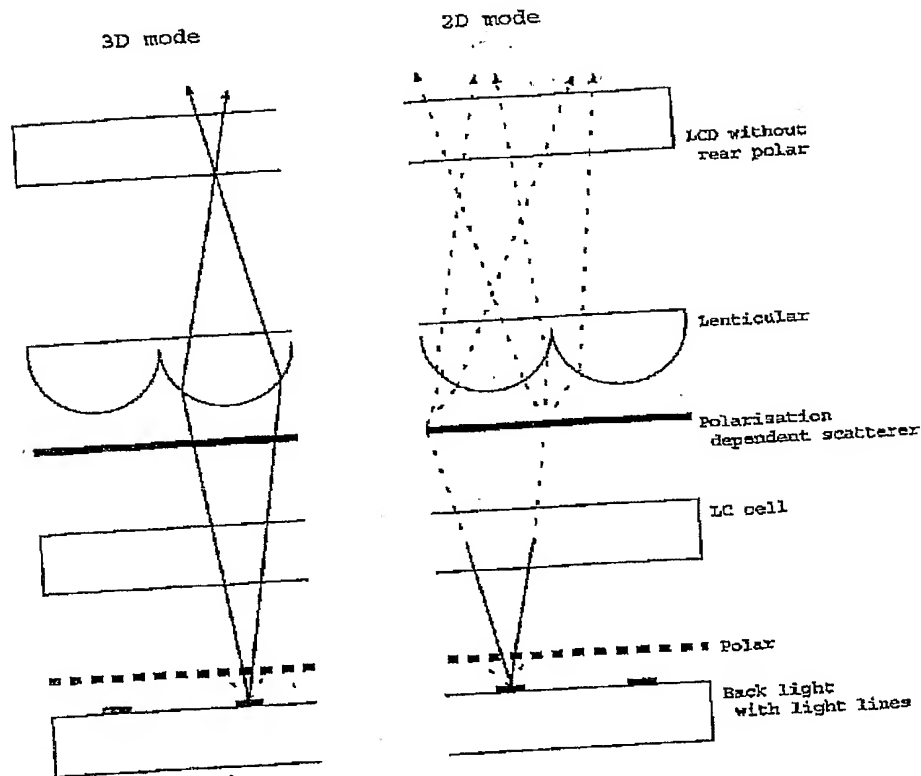


FIGURE 7

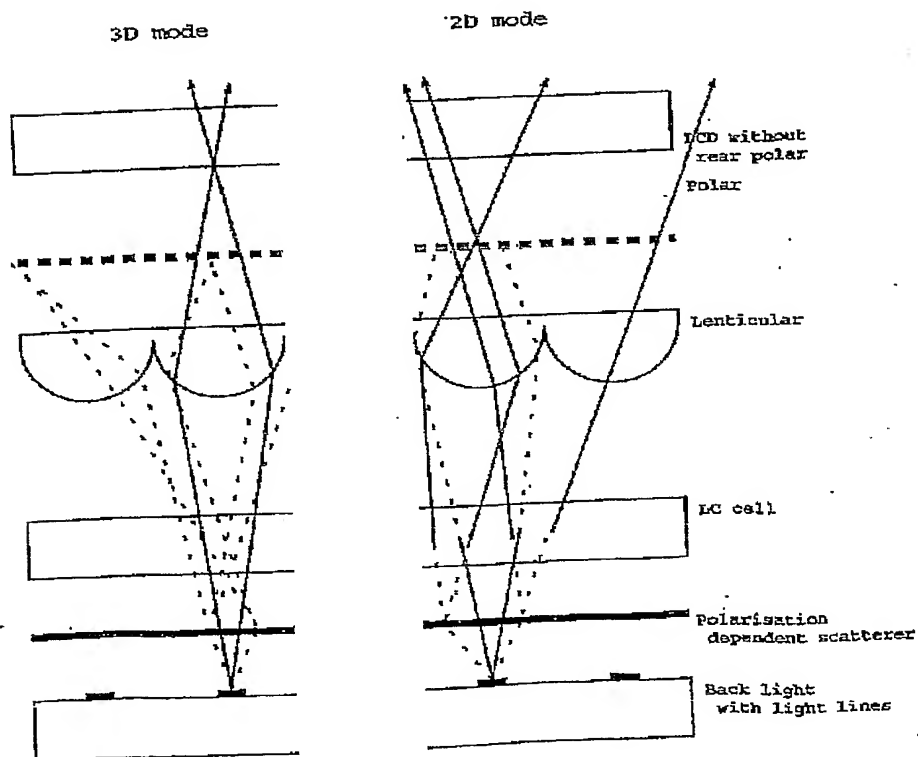


FIGURE 8

PHG8030215



5/11

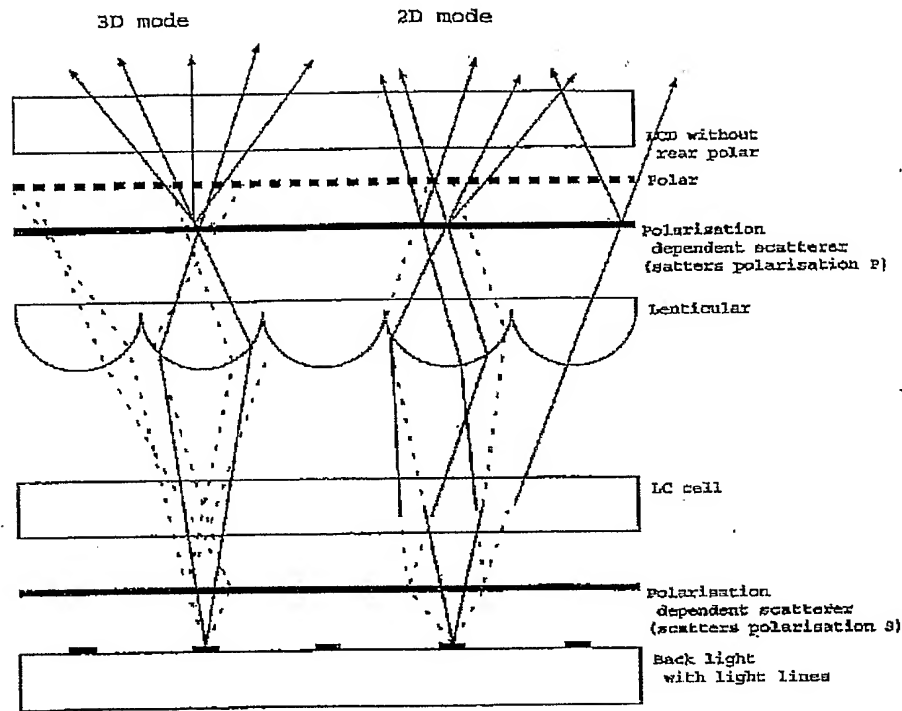


FIGURE 9

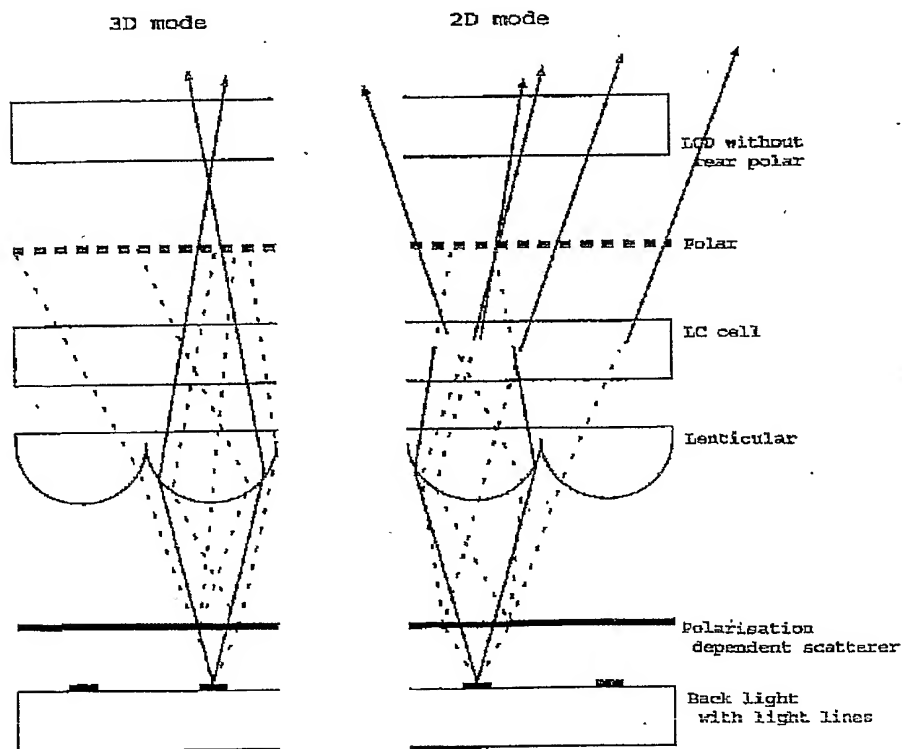


FIGURE 10

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6/11

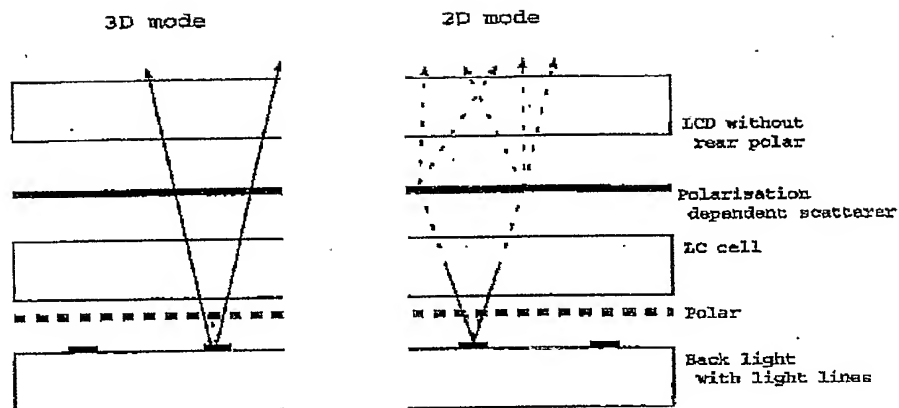


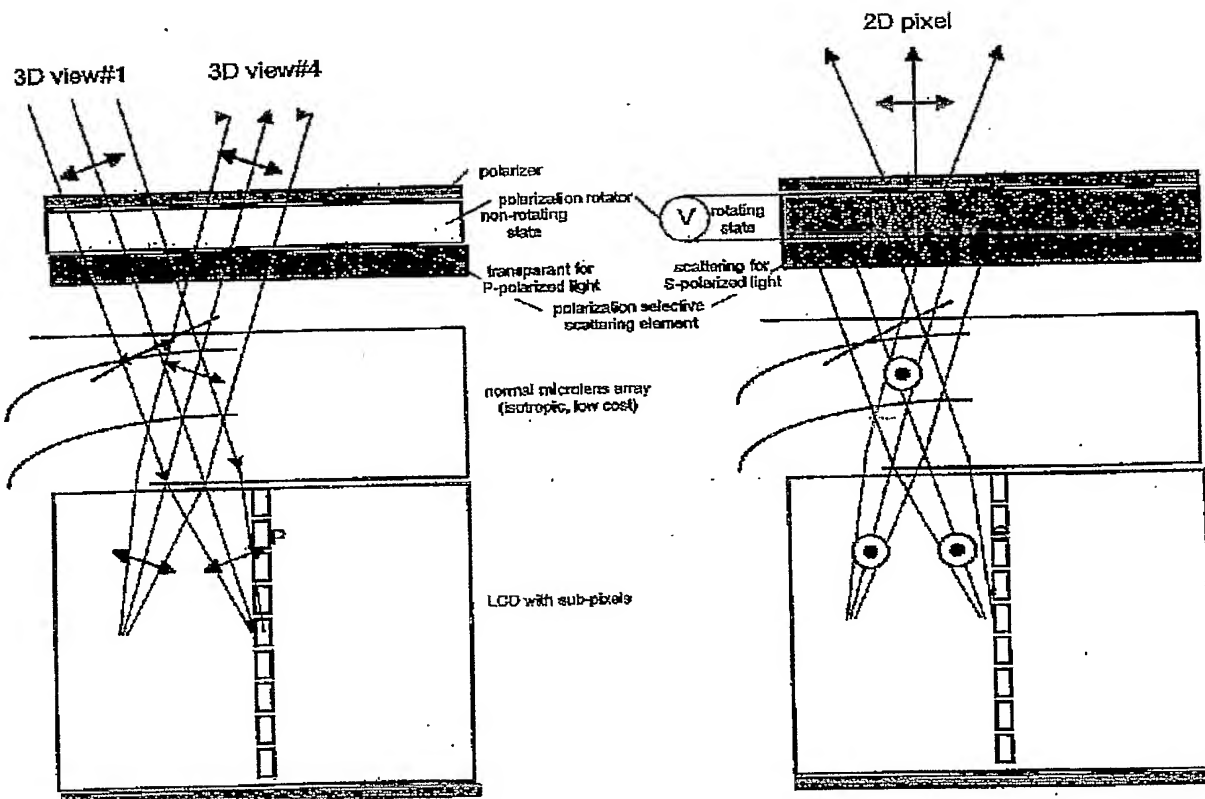
FIGURE 11.

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7/11



1-st Embodiment where the stack comprises an isotropic microlens array, a polarization selective scattering element, switchable polarization rotator (?/2) and a polarizer.

FIGURE 12.

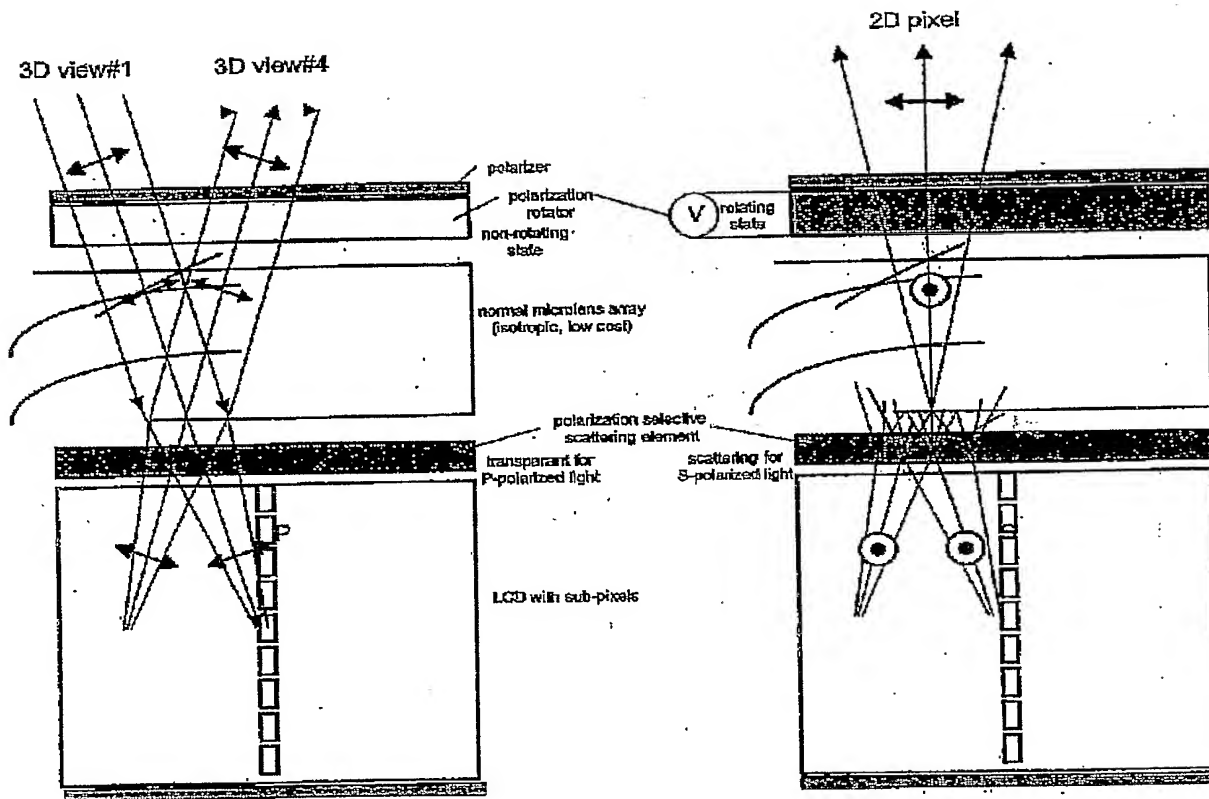
3D MODE:  
best, because of small distance between lenses and subpixels  
2D MODE:  
relatively large distance from subpixels to diffuser 5  
means loss of 2D resolution

FIGURE 13

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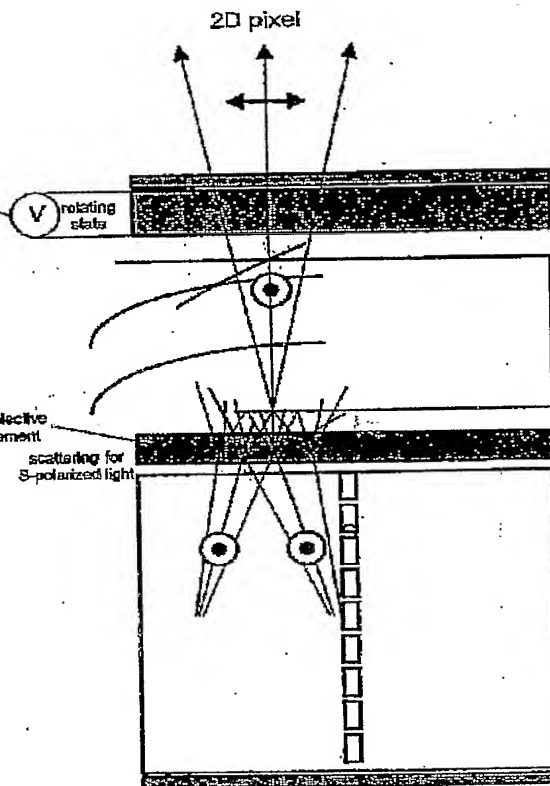


8/11



2-nd Embodiment where the stack comprises a polarization selective scattering element, an isotropic microlens array, switchable polarization rotator ( $\pi/2$ ) and a polarizer.

FIGURE 14



3D MODE:  
larger distance between lenses and subpixels means that views are somewhat less separated  
2D MODE:  
best, because of small distance from subpixels to diffuser

FIGURE 15

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9/11

# 1-st Example of polarization selective scattering element

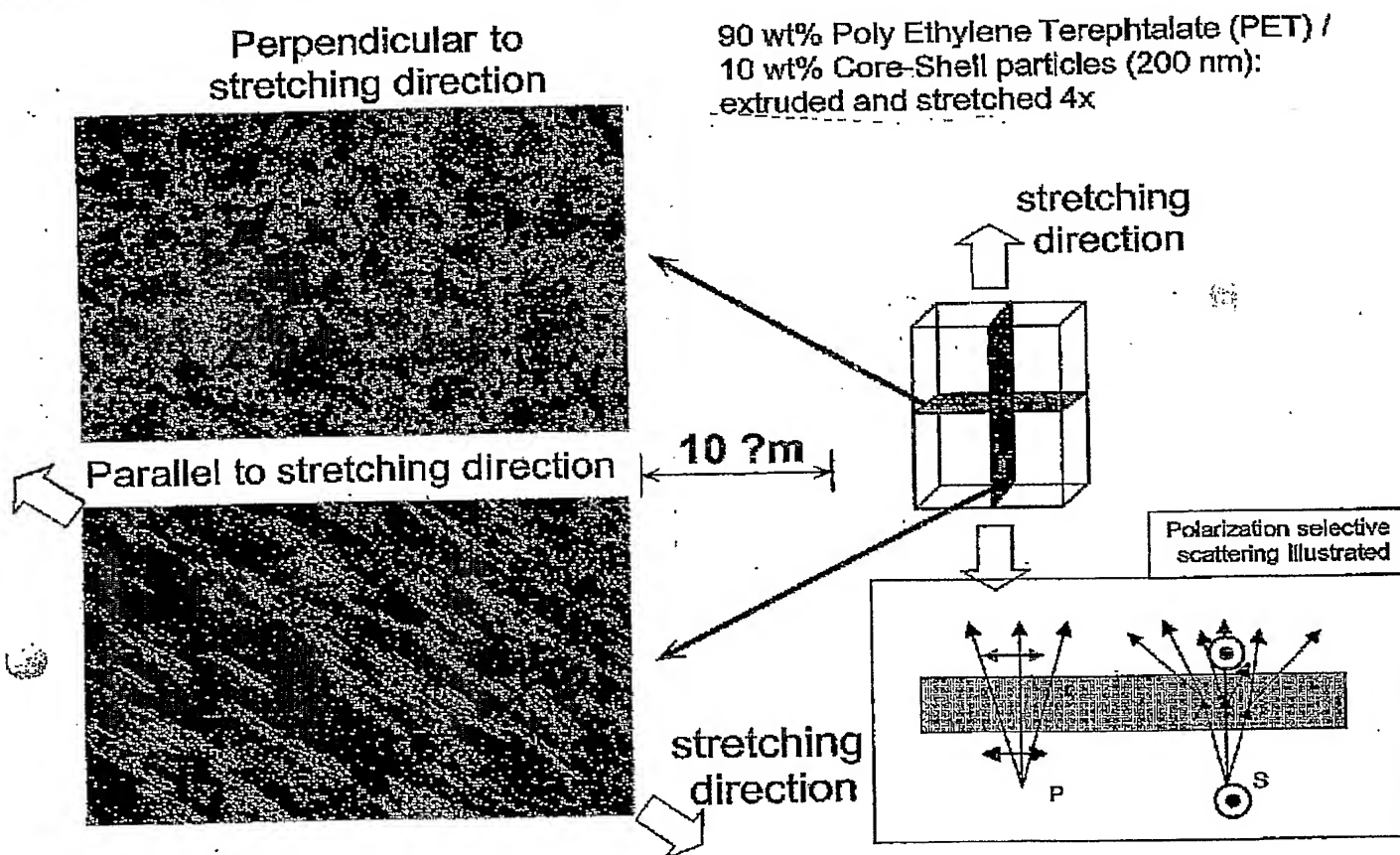


FIGURE 16

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10/11

## 2-nd Example of polarization selective scattering element

Poly Ethylene Terephthalate (PET) foil or Poly Ethylene Naphtalate (PEN or similar:

- foil extruded
- stretched 4-5x: index of refraction  $n_e$  in stretch direction,  $n_o$  perpendicular to stretch direction
- embossed with micro grating pattern
- coated with  $n_o$ -matched top coat

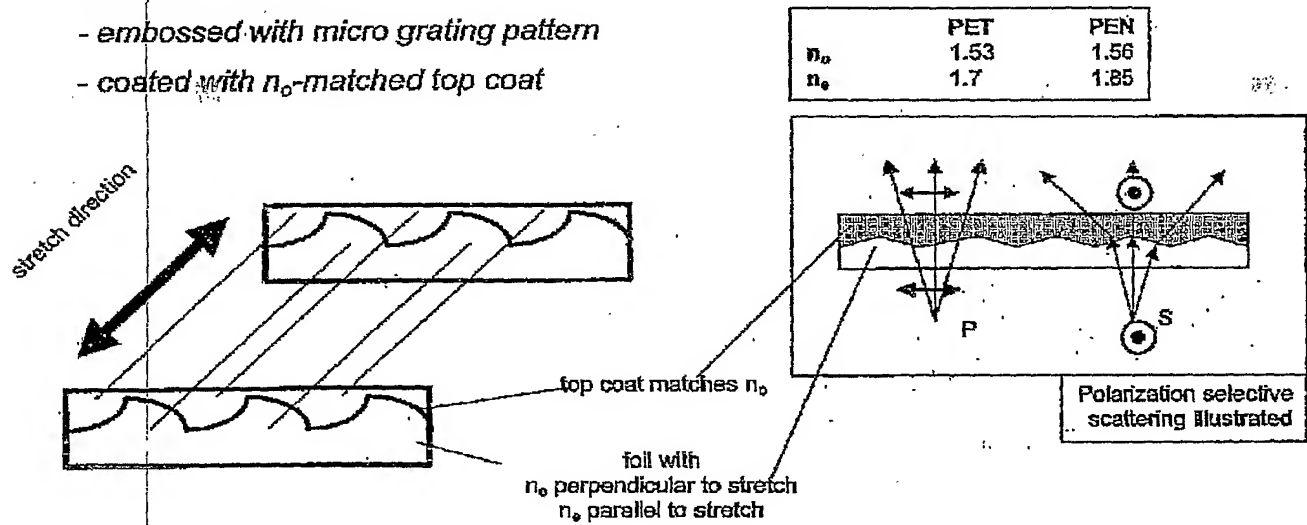


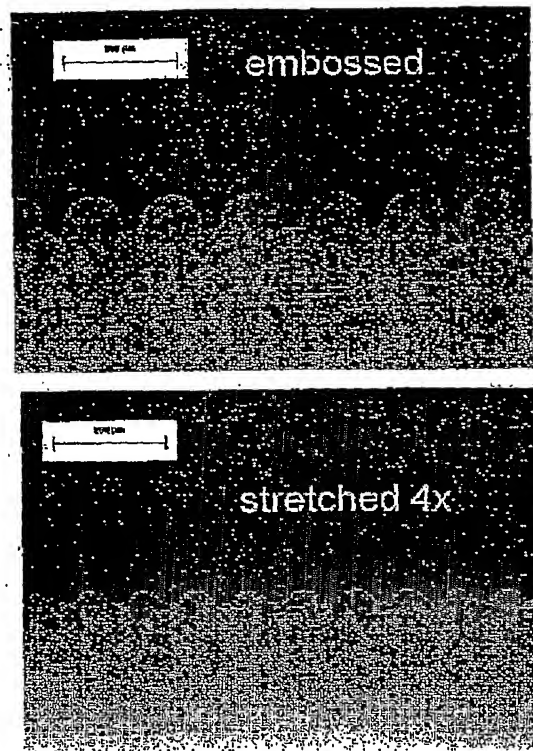
FIGURE 17

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2-nd Example of polarization selective scattering element



9

FIGURE 18

PHGB 030215

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